

Kevlar Window Tensile Tests

Fred Renken

12/23/92

FNAL RD/MSD Thermal Systems

ABSTRACT:

For the new KTeV 1.8 m window tests were necessary to complete safety requirements and assure the window design would meet the necessary standards. Three different configurations were tensile tested to find the torque values necessary to meet requirements based on calculations. It was found that the use of an aluminum gasket increased the clamping capability but also increased damage to the window materials. Without the gasket the clamping fixture slipped at lower loads but held higher maximum loads. Tests with spacers proved that such assemblies would be very difficult to use. Increasing torques will increase the capability of flanges to hold the fixture.

INTRODUCTION:

On the new fixed beam target experiment KTeV, a 1.8 m diameter vacuum chamber window will be constructed for experimentation. This window, although very like others built in the past, is much larger and so extra safety precautions and documentation is needed. The window is constructed of a kevlar fabric sheet for strength between layers of mylar for protection and vacuum seal.

Three different clamping configurations were tested. The first clamp was the same as the fixture used on previous windows with a soft alloy aluminum gasket to achieve a tight seal and account for tolerances in bulk head construction. The second was to test without the gasket, holding the window between only the two bulk heads. Steel inserts were placed in the test samples to simulate a flat bulkhead. In order to use this configuration much tighter tolerances in the bulk head construction will be necessary in order to achieve a vacuum tight seal. The third test was conducted with metal spacers between the flanges inside the window materials to assure bulkhead strength. These tests required the use of the aluminum gasket.

Several aspects of the window were examined in each test. First, would the clamping assembly itself damage the window materials beyond usefulness by compressive forces cutting through the materials. Second, at what load will the first slip or indication of failure occur. At what clamping force or torque would the necessary load be upheld. Most importantly, what maximum load can be sustained in each configuration. Finally, the overall damages and performance of the test samples used.

The window bulkhead flanges were simulated by preparing samples for a tensile test. The clamps were designed to closely simulate the real flanges with both window assembly bolts and through bolts to the vessel. (See drawing numbers 9220.832.ME-285684 and 9220.832.ME-285674) All bolts would be torqued evenly. For this test sample a minimum load of 6845 lbf would be necessary to meet calculations done in an ANSYS analysis of the window. (Attached) The tensile test provides a unidirectional load rather than an even multi-directional force as in the actual window. The actual window should therefore perform better than these tests would indicate.

Test Data

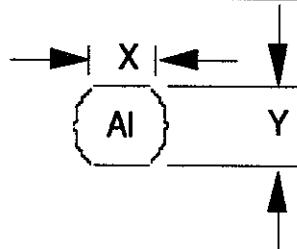


Fig 1: Aluminum Cross Section

5.

Test Data

Test #	Test Speed in/min	Weave degrees	Torque ft*lbs	First Slip lbf	Max Load lbf	Al dim: see fig X	Notes: Y
AI Gasket used: 250 FT*LBS Torque 4 samples							
1	0.05	90	250	7500	11300	0.15	0.152
2	0.05	90	250	6300	9900	0.167	0.156
3	0.05	90	250	7400	10210	0.144	0.152
4	0.05	90	250	7050	11150	0.136	0.154
Average:				7062.5	10640	0.149	0.154
No Aluminum Gasket used.							
1	0.05	90	250	5005	13600	N/A	N/A
2	0.05	90	250	5010	12950	N/A	N/A
3	0.05	90	250	7300	12440	N/A	N/A
4	0.05	90	250	5200	12810	N/A	N/A
Average:				5628.75	12950		
Steel and Aluminum Spacers Used:							
1	0.05	90	250	7050	8000	0.146	0.151
2	0.05	90	250	5800	6810	0.143	0.157
3	0.05	90	250	5700	7005	0.158	0.153
4	0.05	90	250	5210	6100	—	Used Al Spacers
Average:				5940	6978.75	0.149	0.154

OBSERVATIONS:

Based on the best representative sample from each different clamping configuration.

Aluminum gasket 250 ft*lbf with 90° weave. (Test #12)

- Kevlar: Failure along aluminum gasket location.
Failures due to fraying and slip from around bolt holes.
- Mylar: Clearly indented along aluminum gasket. No holes or tears.
- Data Curve: Smooth with only 2 slips before maximum load reached.

Aluminum gasket 250 ft*lbf with 45° weave. (Tests #19 and #20)

- Kevlar: No failure by bolts or aluminum clamp.
All failure in center region 3.75 inches wide.
- Mylar: Some indentation along gasket. One tear at frayed corner.
- Data Curve: Apparent yield point exists present.
Very smooth line without slips or failures until maximum load reached.
The yield could not be calculated because the load takes a hyperbolic shape for which the cross sectional area is indeterminate.

No aluminum gasket 250 ft*lbf 90° weave. (test #21)

- Kevlar: Failure outside clamped regions.
Failure areas lined up between bolt locations.
Fraying along edges very evident.
- Mylar: Fused slightly to kevlar. Easily removed with very little damage.
No indentations except slight cloth weave pattern.
- Data Curve: Multiple slips and failures before maximum load reached.

Spacers with aluminum gasket at 250 ft*lbf 90° weave. (test #25)

No significant difference in performance of aluminum spacers and steel spacers.

- Kevlar: Severe failure along Al gasket. Bolt holes remain intact.
Little fraying except along edges.
- Mylar: Both gasket and spacer indentations visible. No tearing, remained intact.
- Spacers: Some seemingly untouched, others severely indented or bent. Aluminum spacers sustained more damage.
- Data Curve: Smooth until several failures immediately before maximum load.

DISCUSSION OF DATA:

All tests had failures resulting from fraying along exposed edges. This would not happen if fabric pulled uniformly in all directions. Fraying would also be reduced with the use of epoxy as all previous windows were constructed. The actual window would be able to sustain higher loads than tensile samples.

45° weave tests formed hyperbolic shaped tension region resulting in higher fraying and indeterminable cross sectional area. Most 45° weave tests results are not helpful contributors to the data desired.

First eleven tests used to find minimal torque at which target loads of 13094 and 6845 lbf would be met or exceeded.

Widespread values of maximum loads indicate tests not completely valid. Experience and design theory should not be blatantly overridden by these results.

Data for the first slip and maximum load included to provide information on which to base safety factors. Fraying edges often the cause for first slip. At this value vacuum may be lost, in the window application, but no severe endangering failure would occur.

Tests in which spacers were used suspect because of the difficulty in assembly of test samples. The difficulty and failure to assemble good samples clearly shown by damage to the mylar and spacers. Better assembly needed than could be done with this test apparatus.

NOTE: Scales change from test to test on graphs so read test curves carefully.

NOTE: The machine could test to a maximum load of 13000 lbf so tests at higher torques were not done.

CONCLUSIONS:

Tears in mylar pieces was primarily due to slips after the maximum load failure, not from the assembly process. The damage incurred because test was taken to failure. The mylar did become permanently indented.

At 250 ft*lbf a total bolt load of 54395 lbf is exerted on the fixture. The resulting average X dimension on the aluminum gasket of 0.149 yields a compressive force of 37032 psi. This compressive force is higher than mylar's yield and ultimate strengths but failure did not occur since mylar is extremely elastic. This force is below the strength of kevlar so no damage to the cloth was induced by the assembly.

Significantly less damage to the mylar occurred on the tests without the aluminum gasket.

250 ft*lbf torque was necessary with the aluminum gasket to obtain a first slip above the desired 6845 lbf. The first slip for samples without a gasket occurred at a much lower value than either with the gasket or the desired load. Therefore the aluminum gasket significantly aided a secure hold.

The aluminum gasket was not deformed to flush with the clamping fixture and did supply the primary compressive force. This is clearly shown by an average Y of 0.154 which is greater than the maximum 0.145 depth of the slot.

The highest maximum load at 250 ft*lbf torque was attained without the gasket. this would show that the gasket did contribute to failure at maximum loads.

Spacers yielded unacceptable results for both first slip and maximum load. To align all spacers correctly is very difficult and was never done successfully in these tests.

Increased torques would improve the performance of all fixtures and would be reasonable based on past window construction and performance.

45 psi

K.S2.

ANSYS:

$$T_x = 296280 \text{ lbs}$$

T_x PER LINEAR INCH OF THE CIRCUMFERENCE

$$T_{x_c} = \frac{296280}{\pi(71)} = 1328.2 \text{ lbs}$$

FOR 9-858 WIDE FIXTURE

$$T_{x_g} = \frac{1328.2}{16} = 82.9 \text{ lbs}$$

14.7 psi

ANSYS:

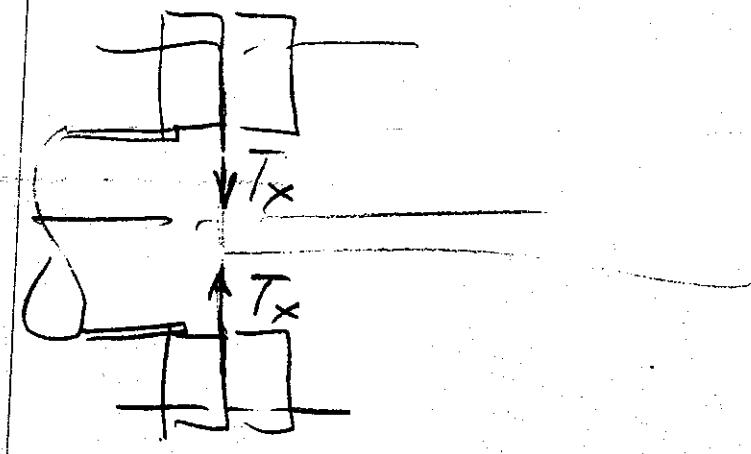
$$T_x = 154880 \text{ lbs}$$

T_x PER LINEAR INCH OF THE CIRCUMFERENCE

$$T_{x_c} = \frac{154880}{\pi(71)} = 694.36 \text{ lbs}$$

FOR 9-858 WIDE FIXTURE

$$T_{x_g} = \frac{694.36}{16} = 43.4 \text{ lbs}$$



KEVULAR

144

TEST #1

SPEED TEST - 0.5 in/min
Tissue 50 FT-LBS

HIGHEST FORCE 2478

NO MULAR
WEAVE 75°

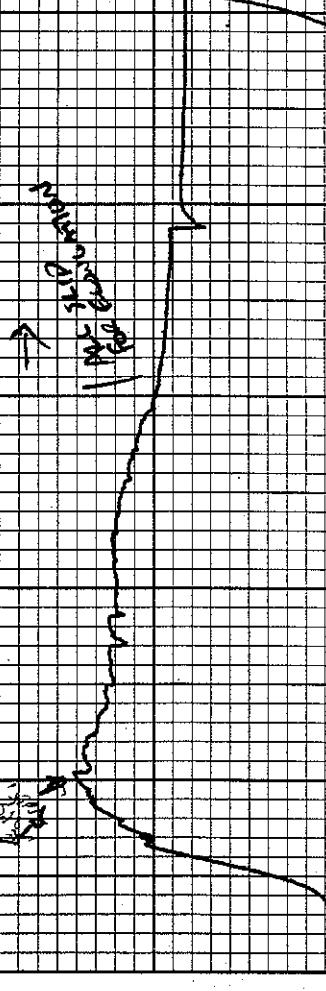
SC 2 PRIMARY ECONOMIC SOURCE
FIRE
EVIDENCE

FIRE
EVIDENCE

12/3/92

EST #2

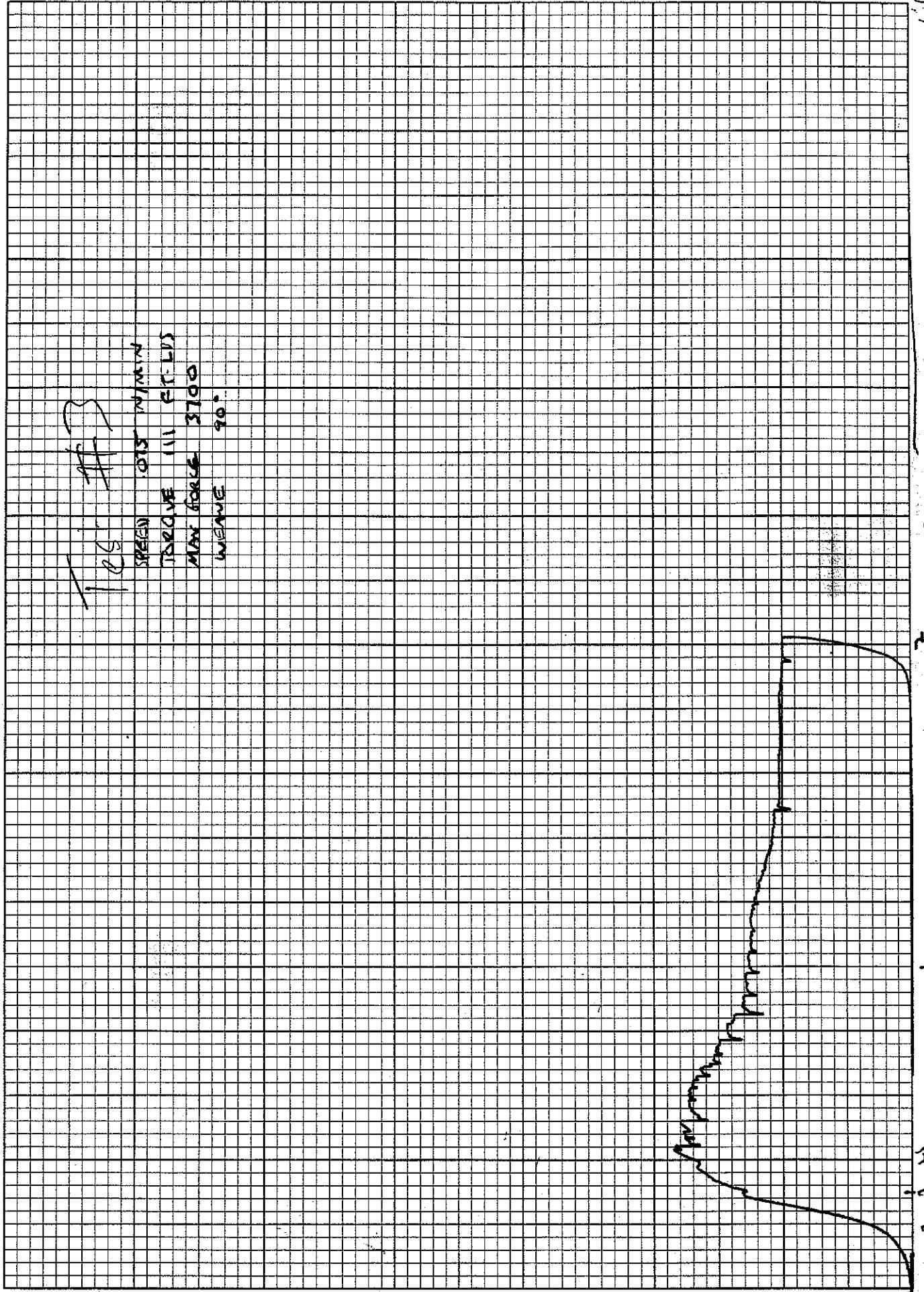
SPEED 0.75 IN/MM.U
TIME 83 FT - 35
AV. FREQUENCY 2810
WAVE 90°



K# KEUFFEL & ESSER CO. MADE IN U.S.A.

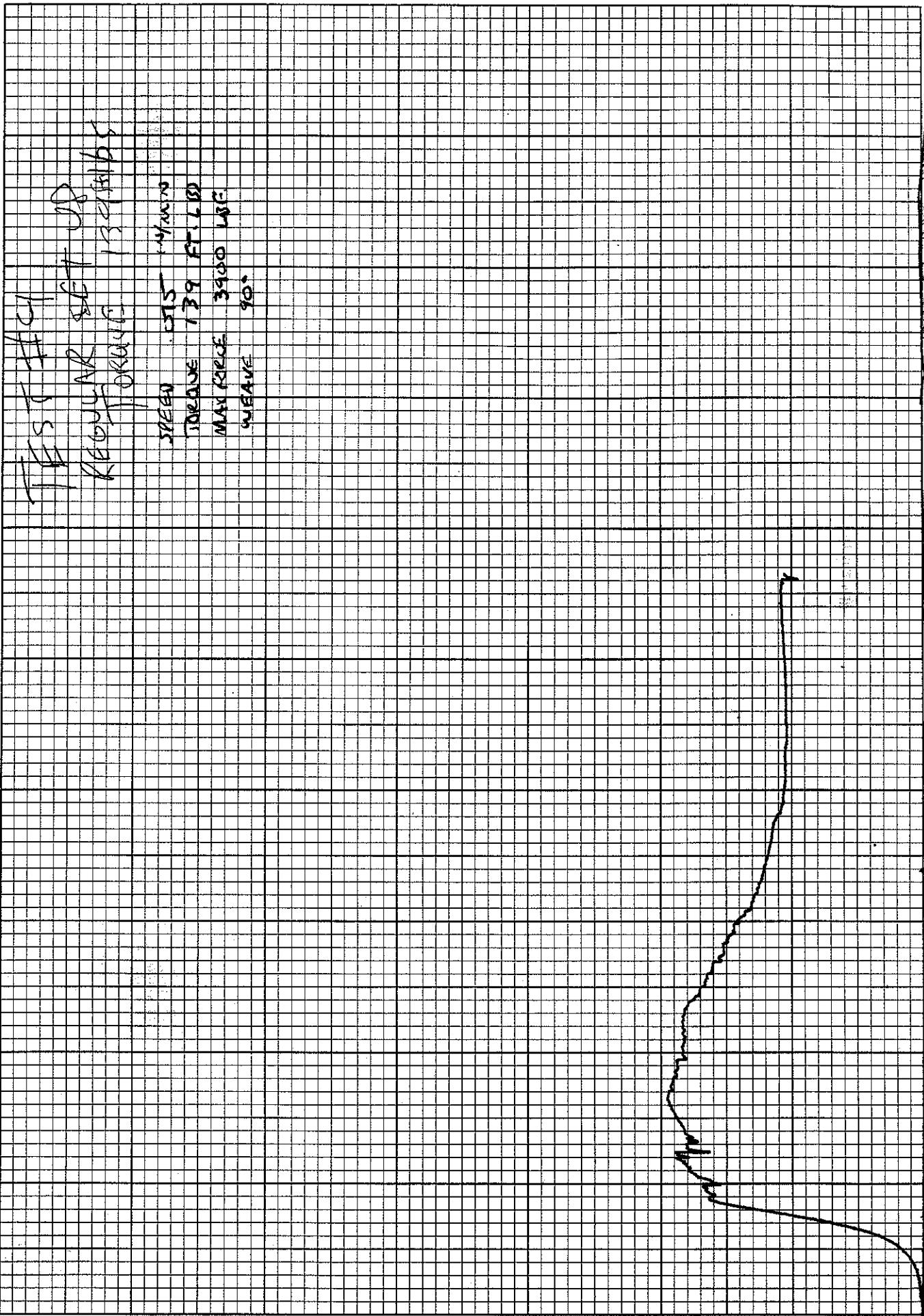
46 0780

SPECIES	0.35	WAVE
DISCOWE	111	ET-LDS
MAN FORCE	3700	
WAVE	90	



7/13.

4



46 0780

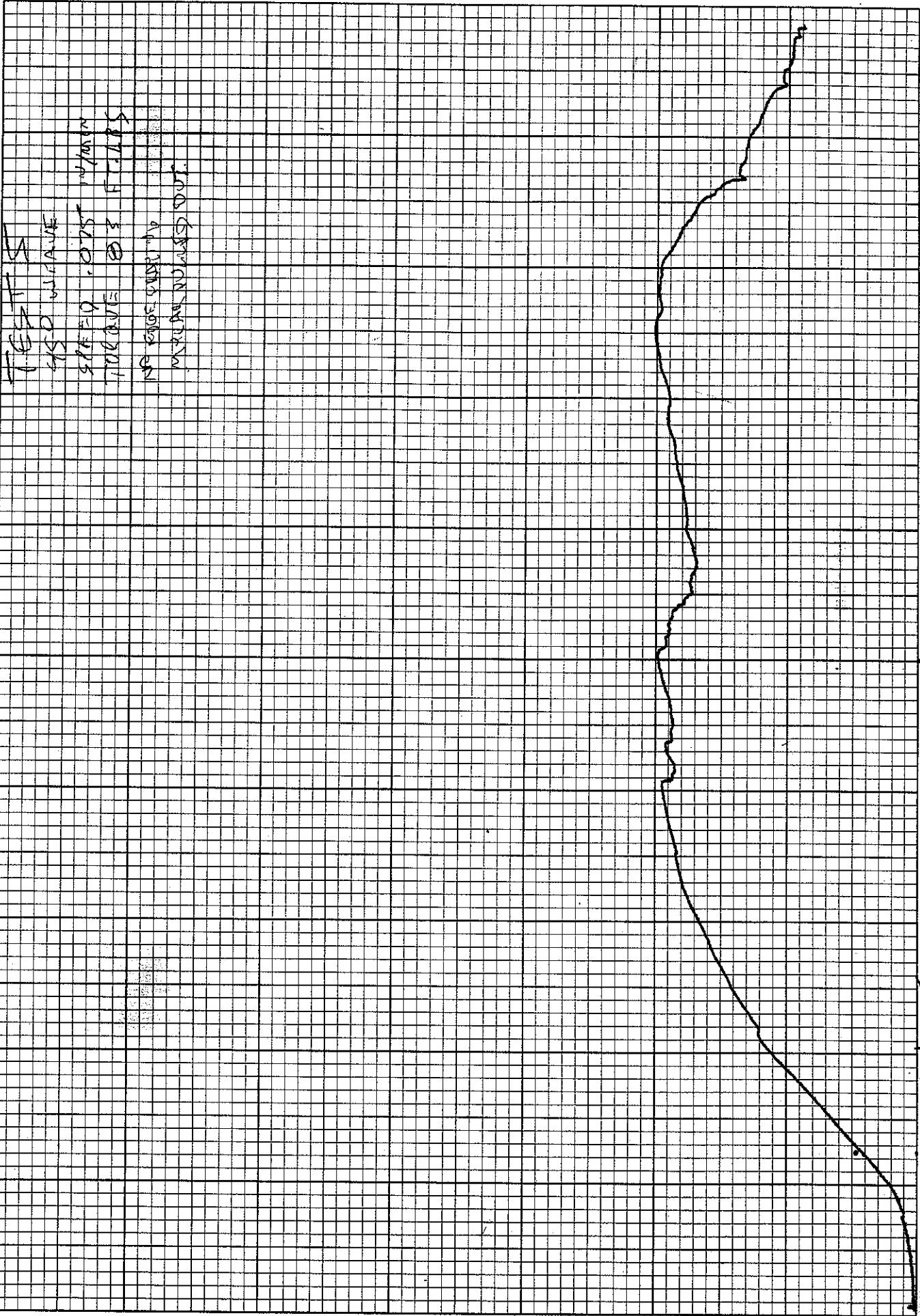
K&E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

148

1491

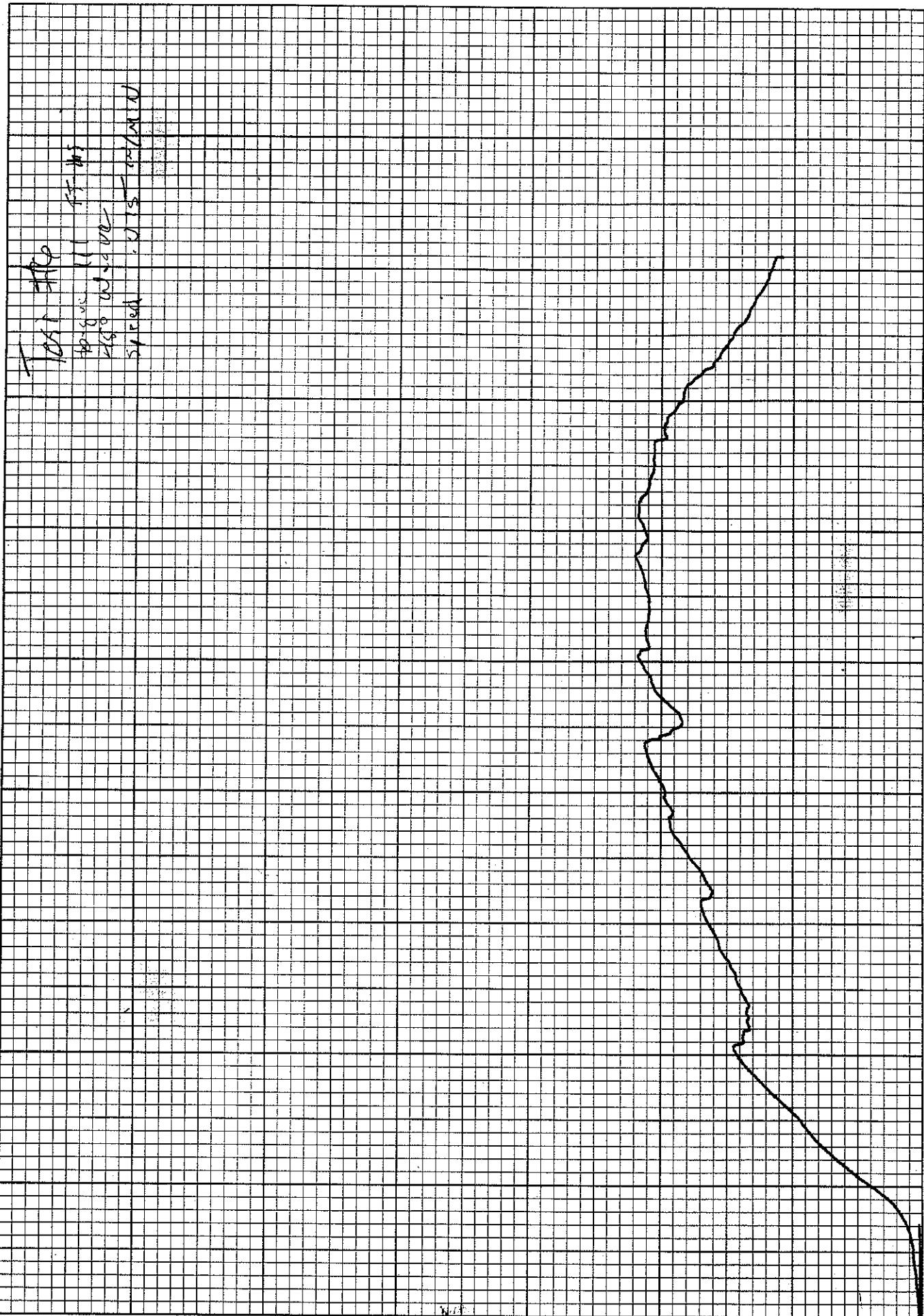
13) 7/12

TEST 5
150 VOLUME
SPF = 9 .075 mm
THICKNESS 23 FT. 1.85
NO GROOVE
MATERIAL DRIED OUT



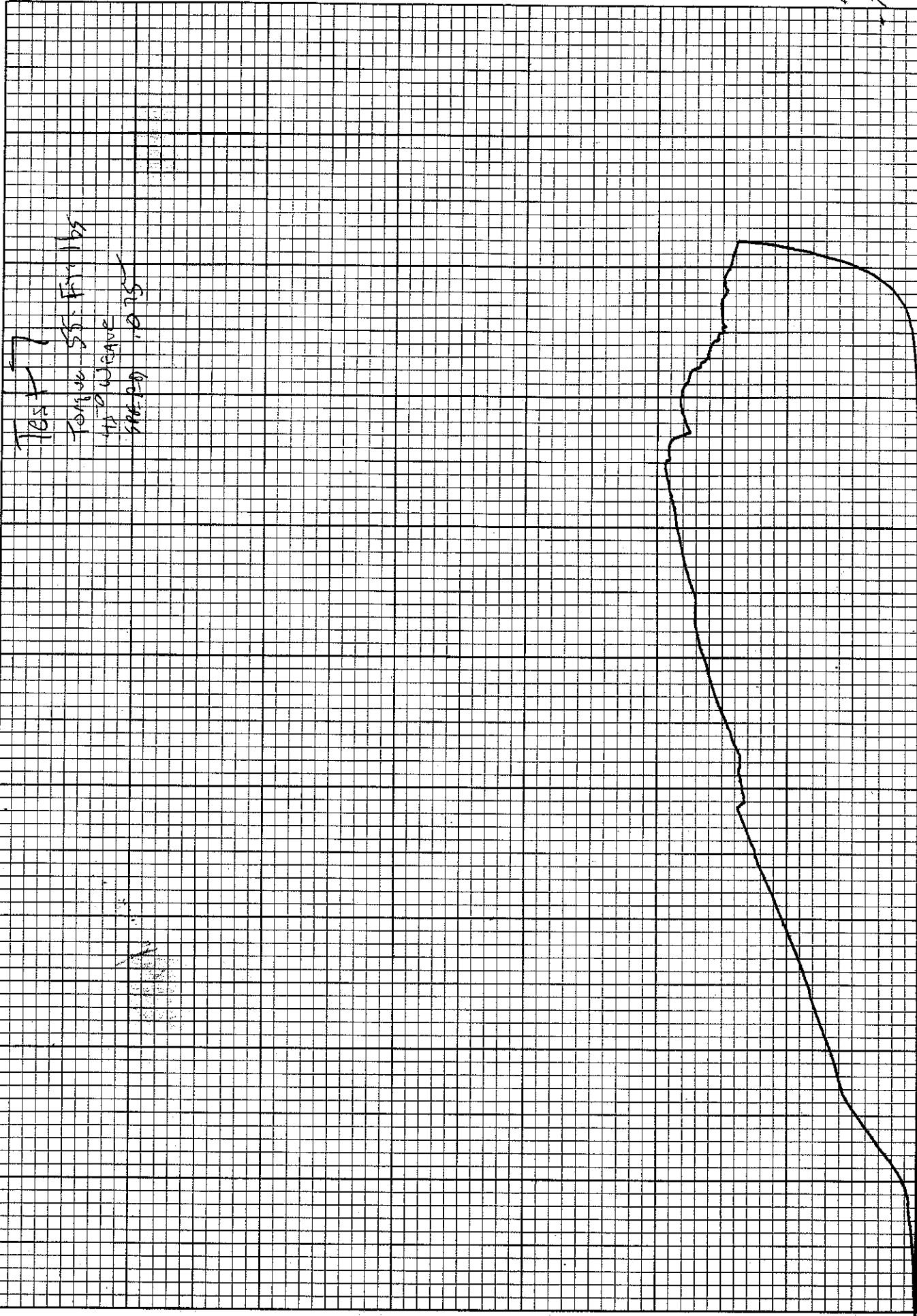
1/5

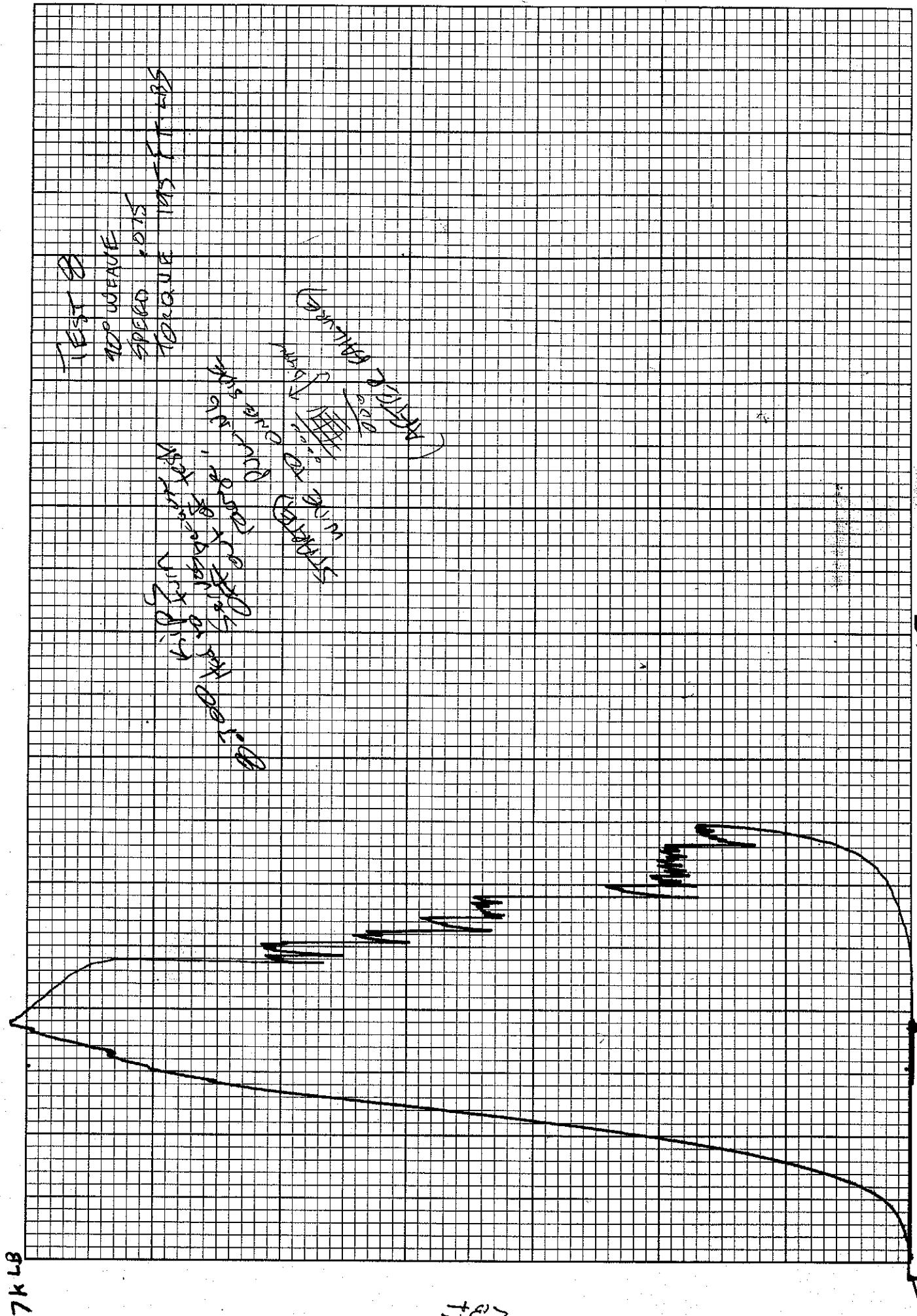
14



K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

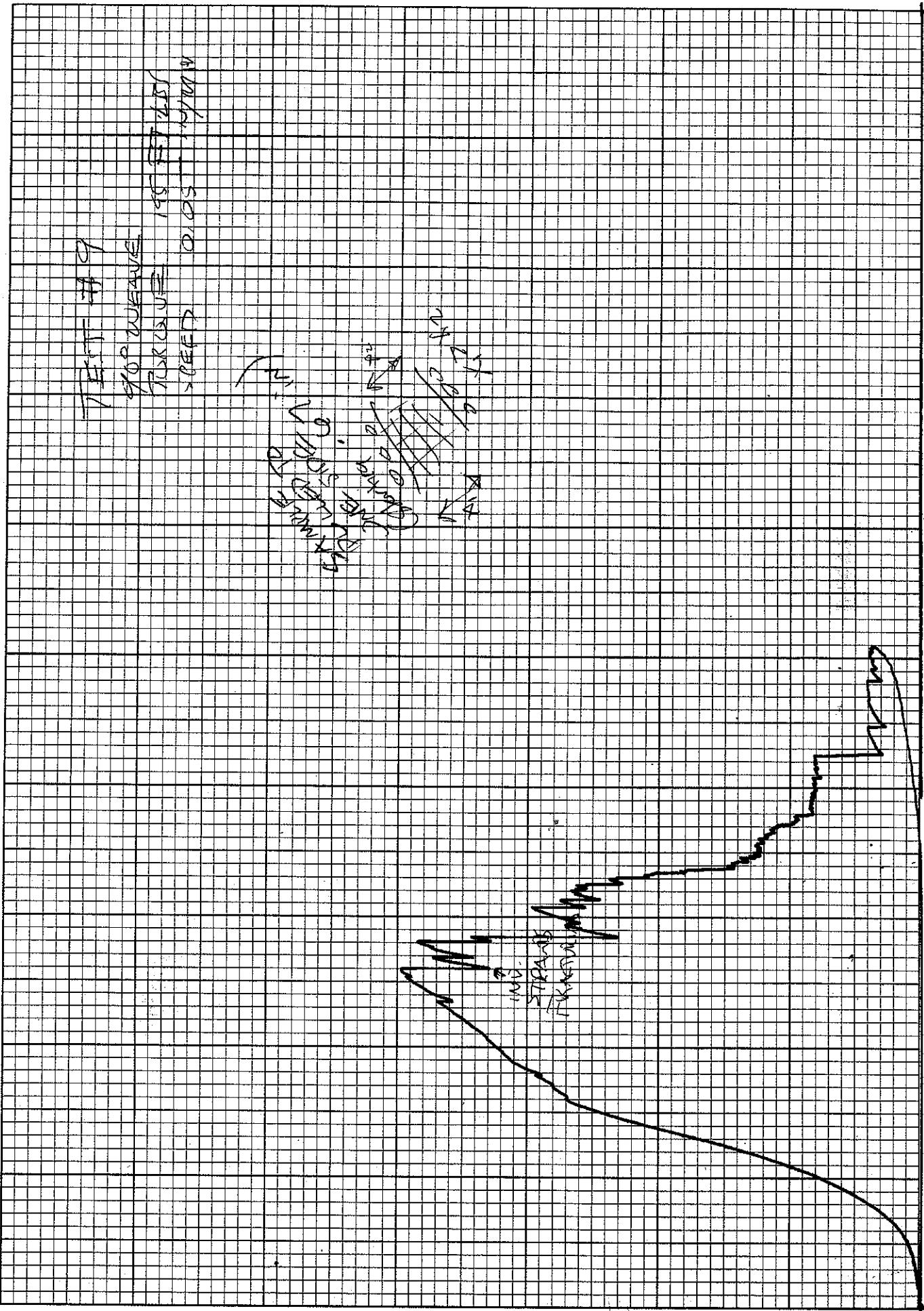
46 0780

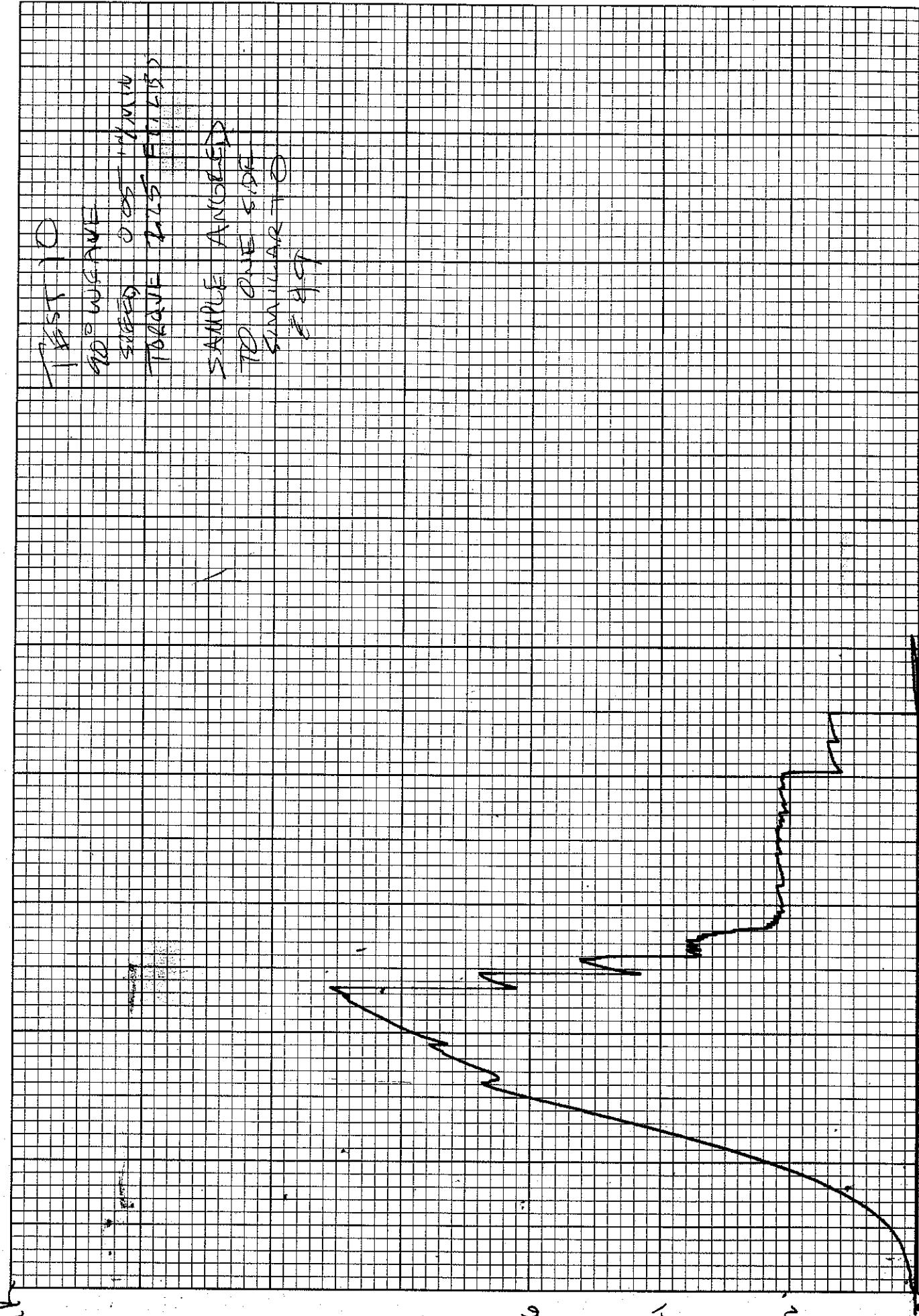




K* KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0780



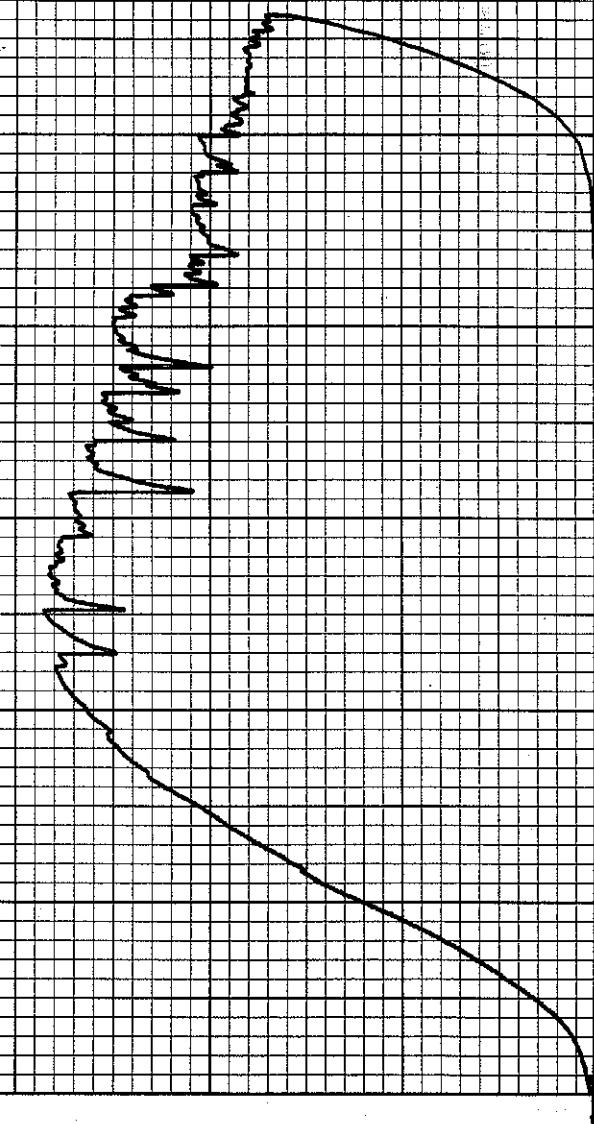


K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0780

TEST #11

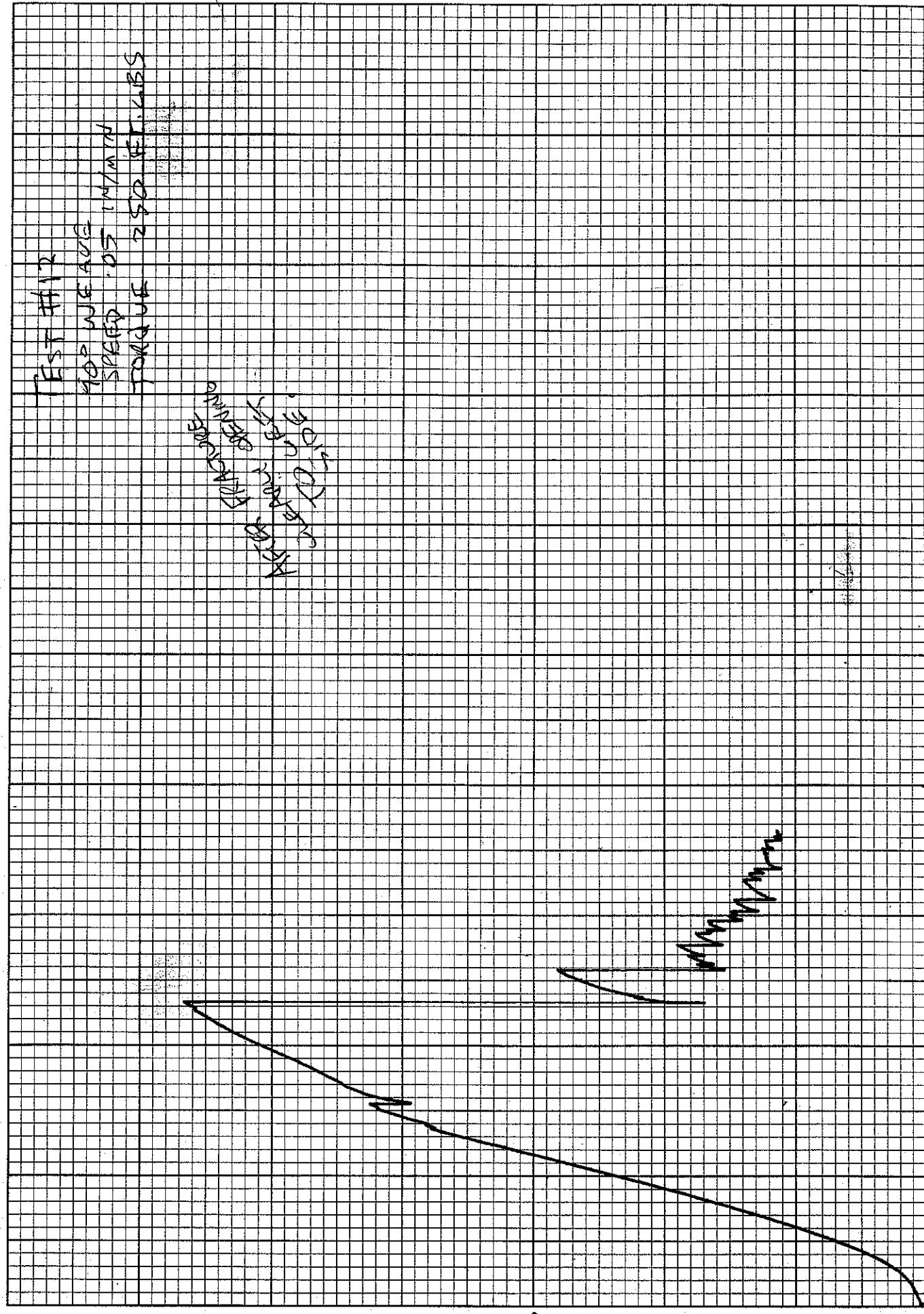
10° WEAVE
5062D 0.05 mm/mm
TAKUE 107 ET 133

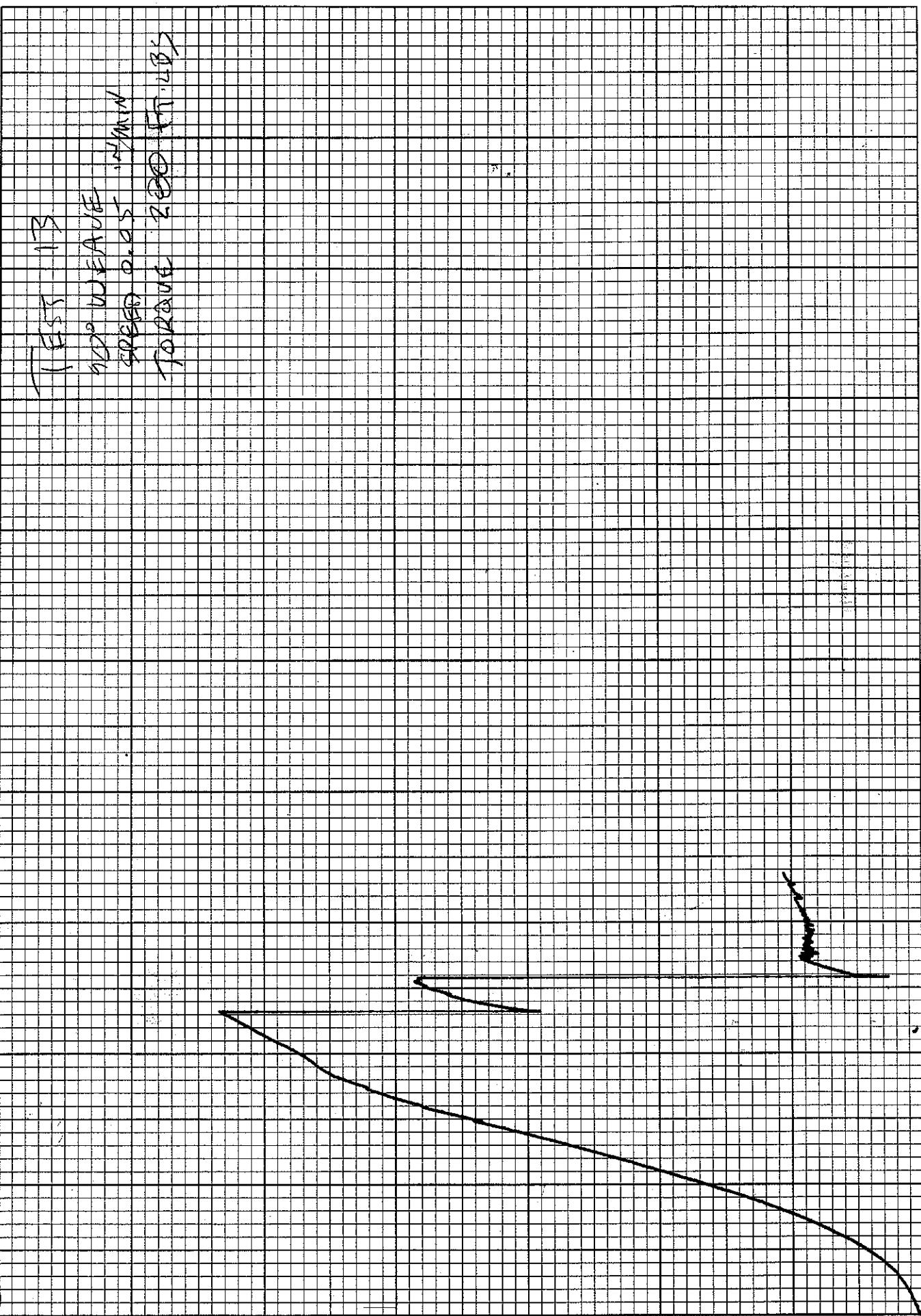


139

K* 10 X 10 TO THE INCH • KUEFFEL & ESSER CO. MADE IN U.S.A.

46 0780



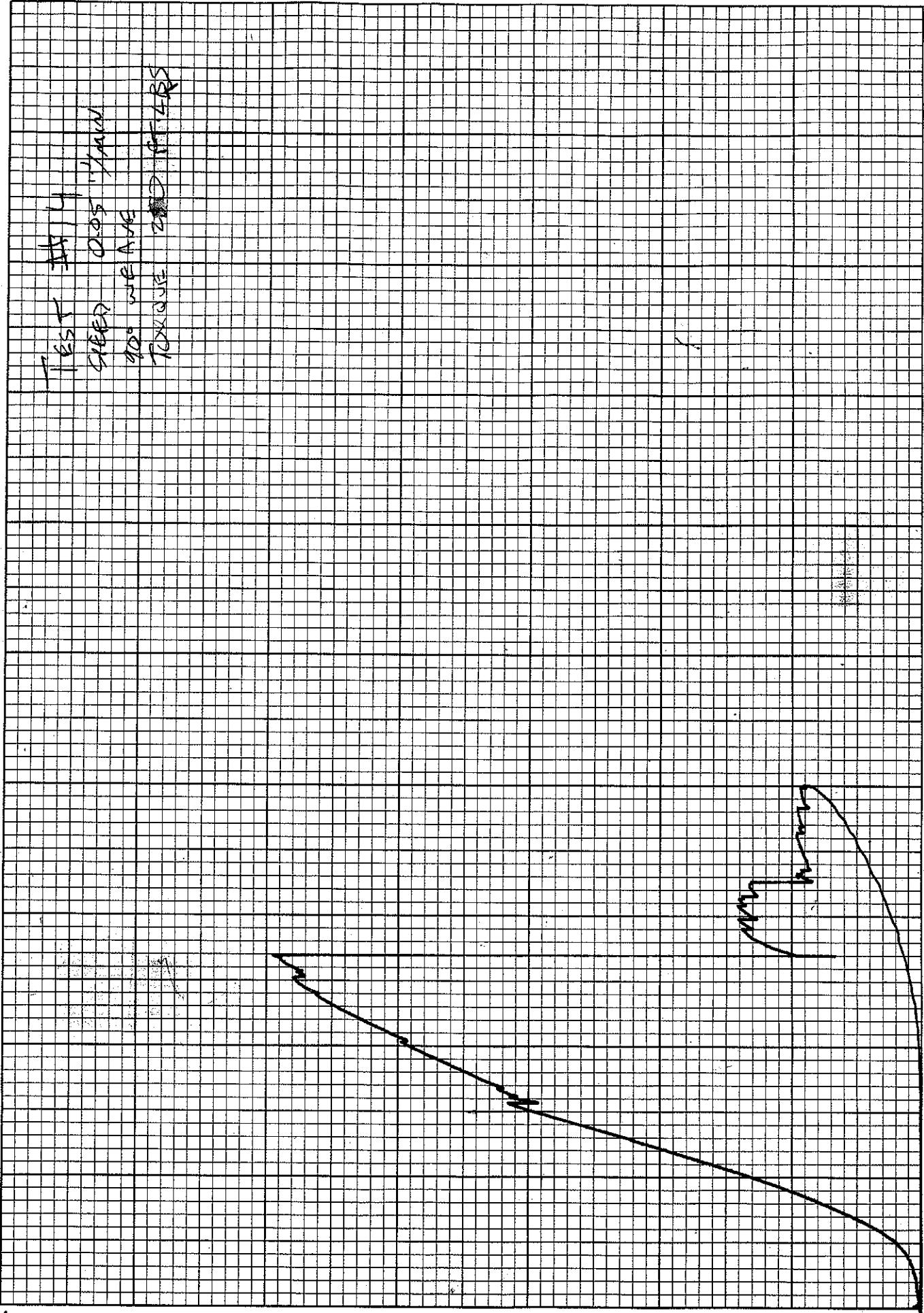


44K

457

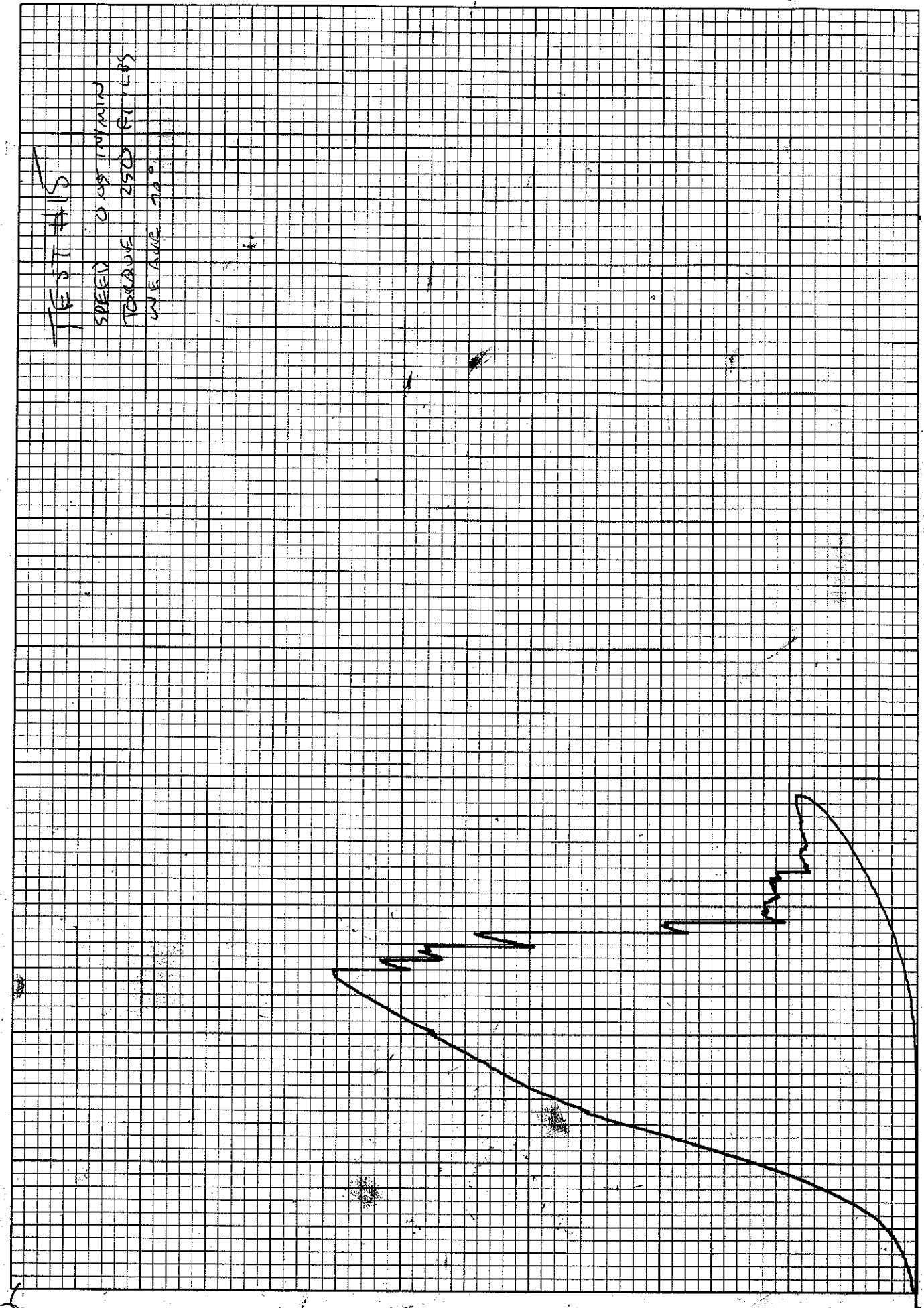
K-10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0780



44

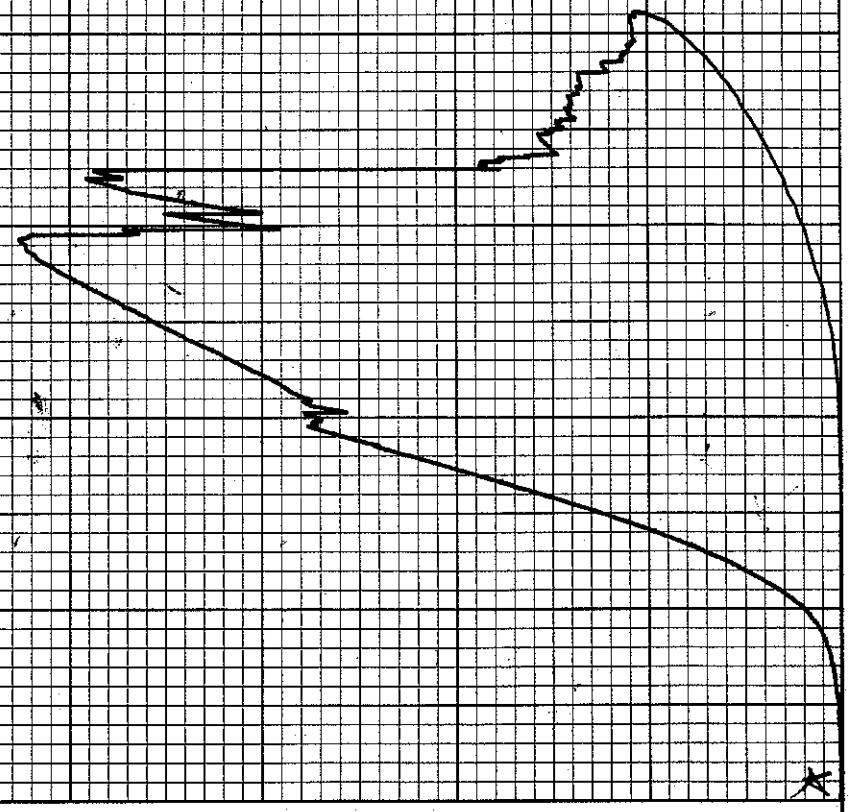
45



46 0780

KELIFFEL & ESSER CO. MADE IN U.S.A.
10 X 10 TO THE INCH • 7 X 10 INCHES

TEST 16

SPEED 200 MM/MIN
TOGGLE 200 FPM
LEAVE 10DO NOT RELOAD
SAMPLE SO HEATED
SHARP.

14K

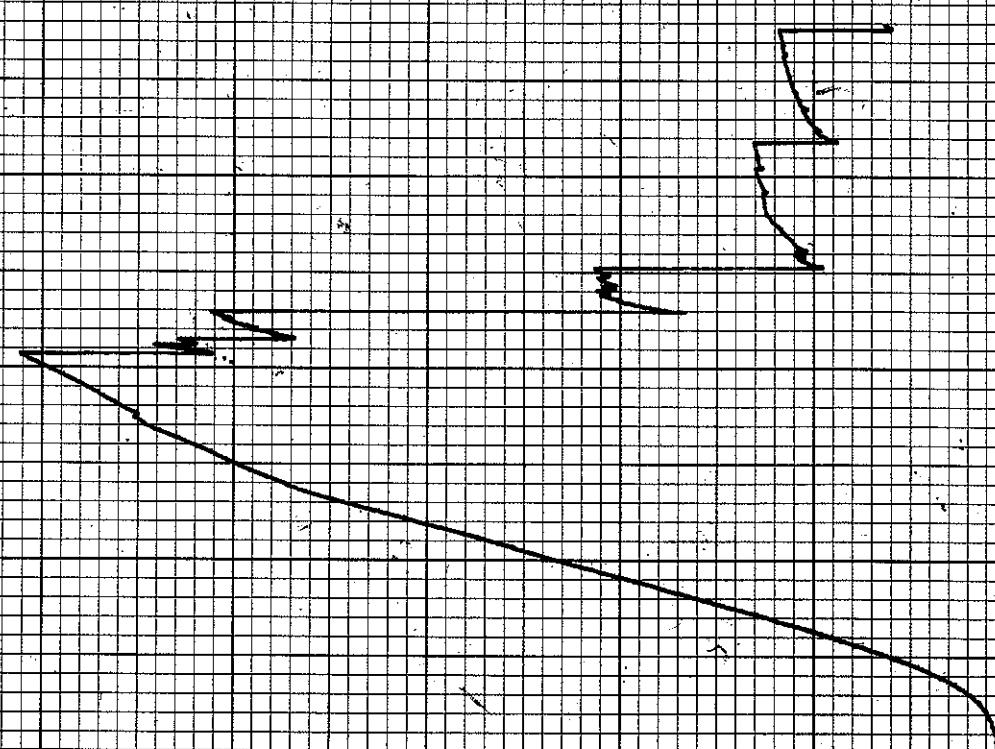
10

K* 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0780

TEST #17
S2020 0.05
10° WETTING
TEST = 150°F, 100% RH

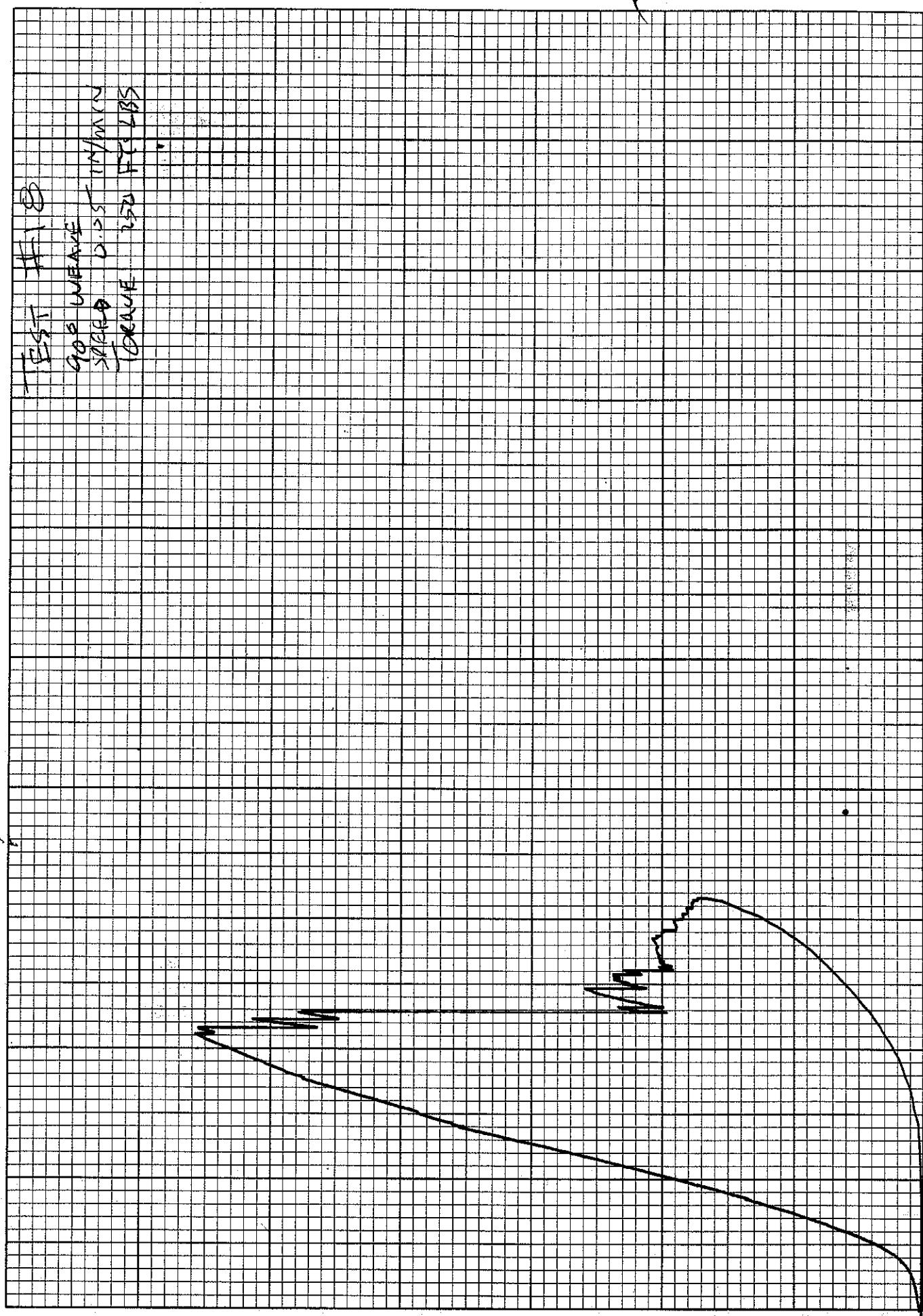
NEUROBOTS



27
2

TEST #18

90° WEDGE
SPANNING 2.25 INCHES
TENSILE 2224 LBS



K-E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0780

TEST #19
SPEED 005 mm/min
WEAVE 45°
TROQUE 250°F 433

1000 mm/mm

100 mm/mm

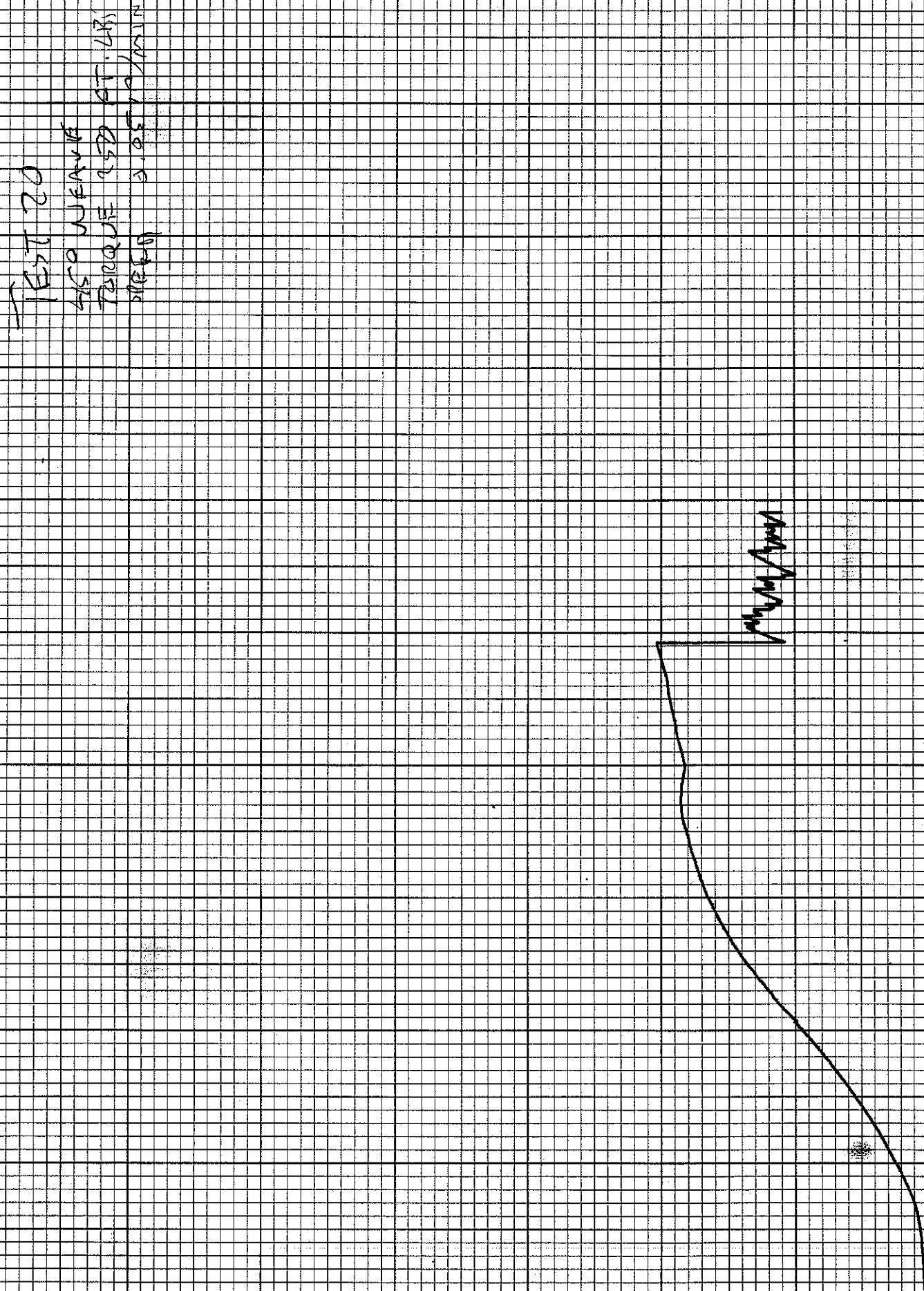
Wk

P8

28.
2

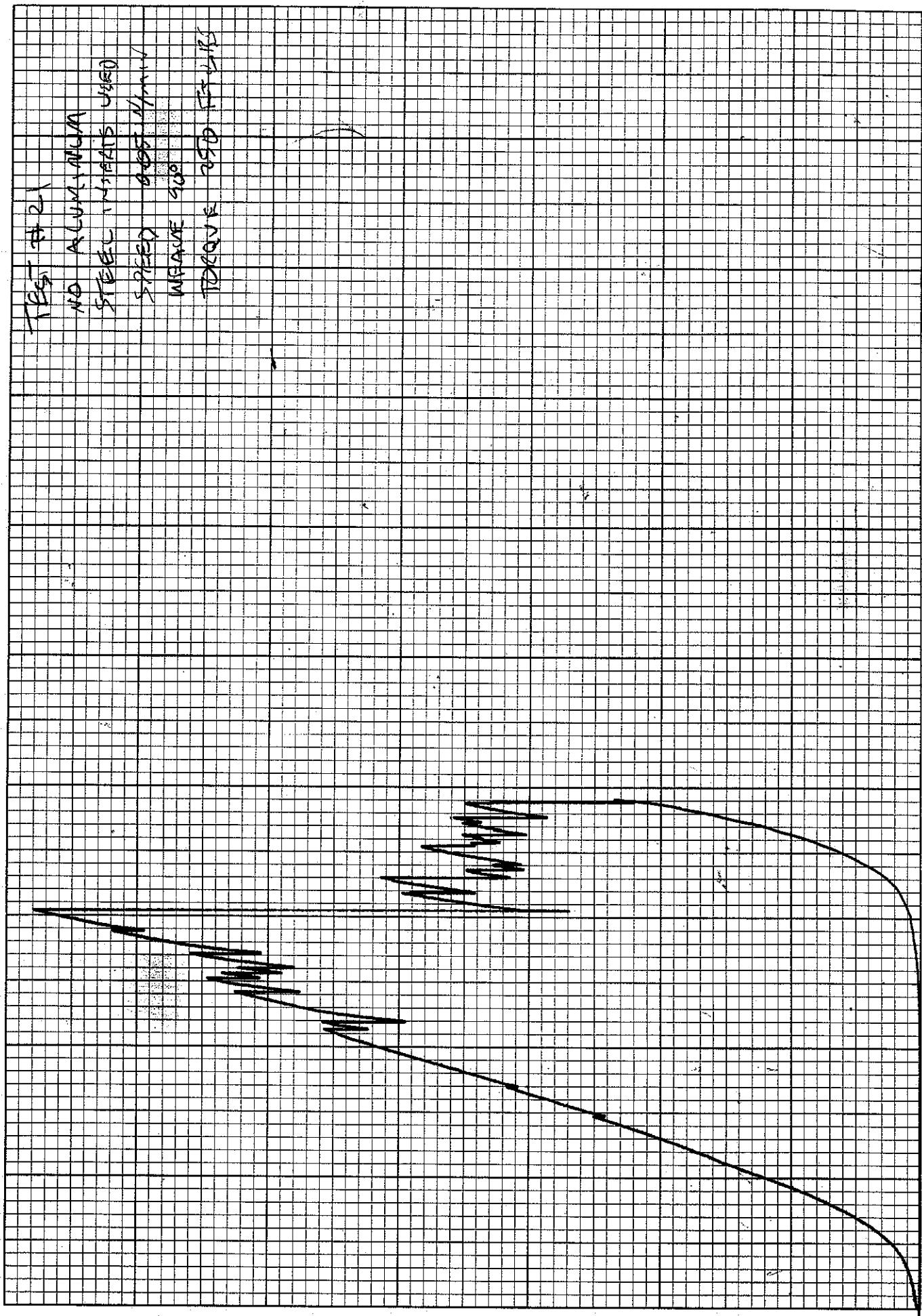
K&E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & LESSER CO. MADE IN U.S.A.

46 0780



46 0780

K*E 10 X 10 TO THE INCH • 7 X 10 INCHES
 KUFPFEL & ESSER CO. MADE IN U.S.A.



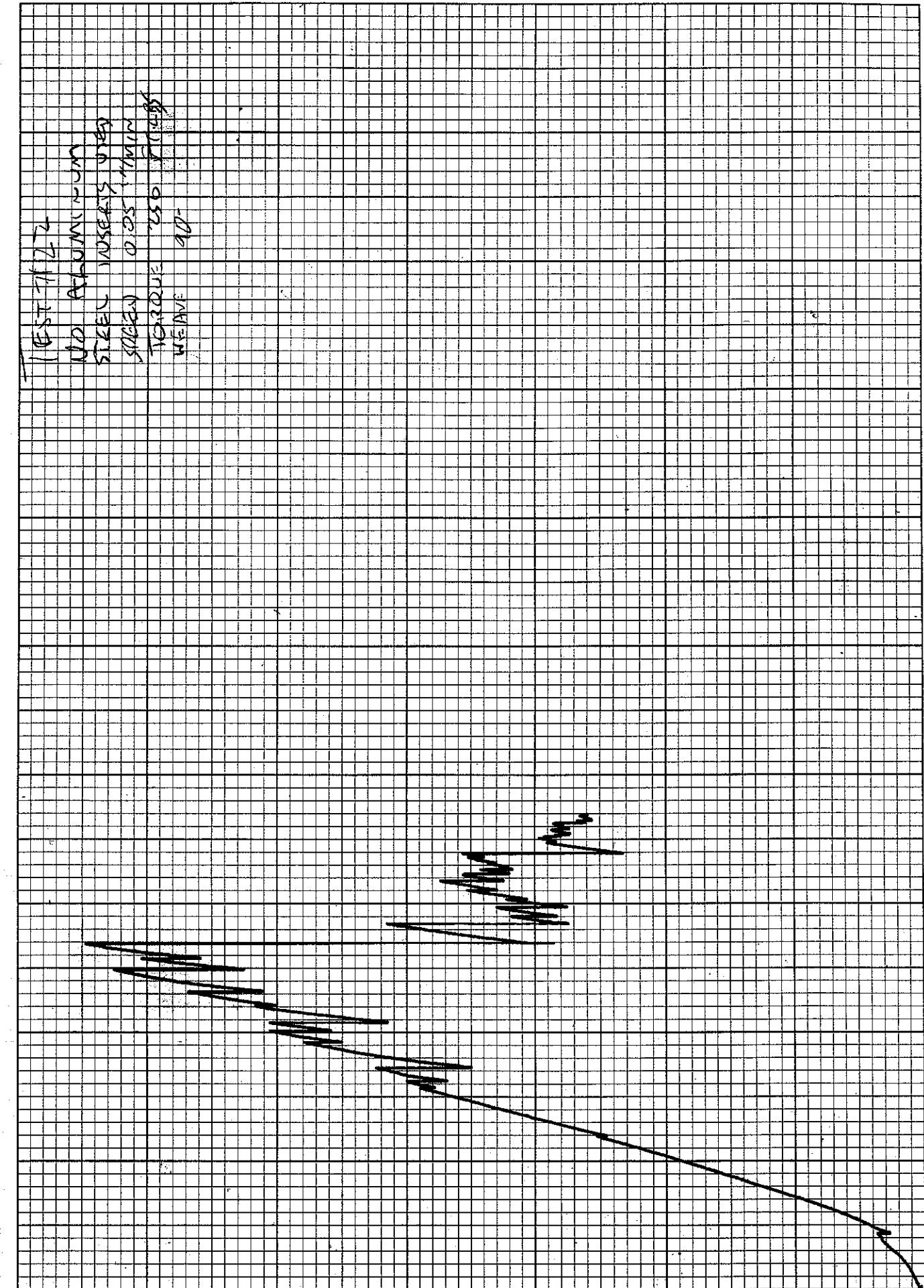
147

100

46 0780

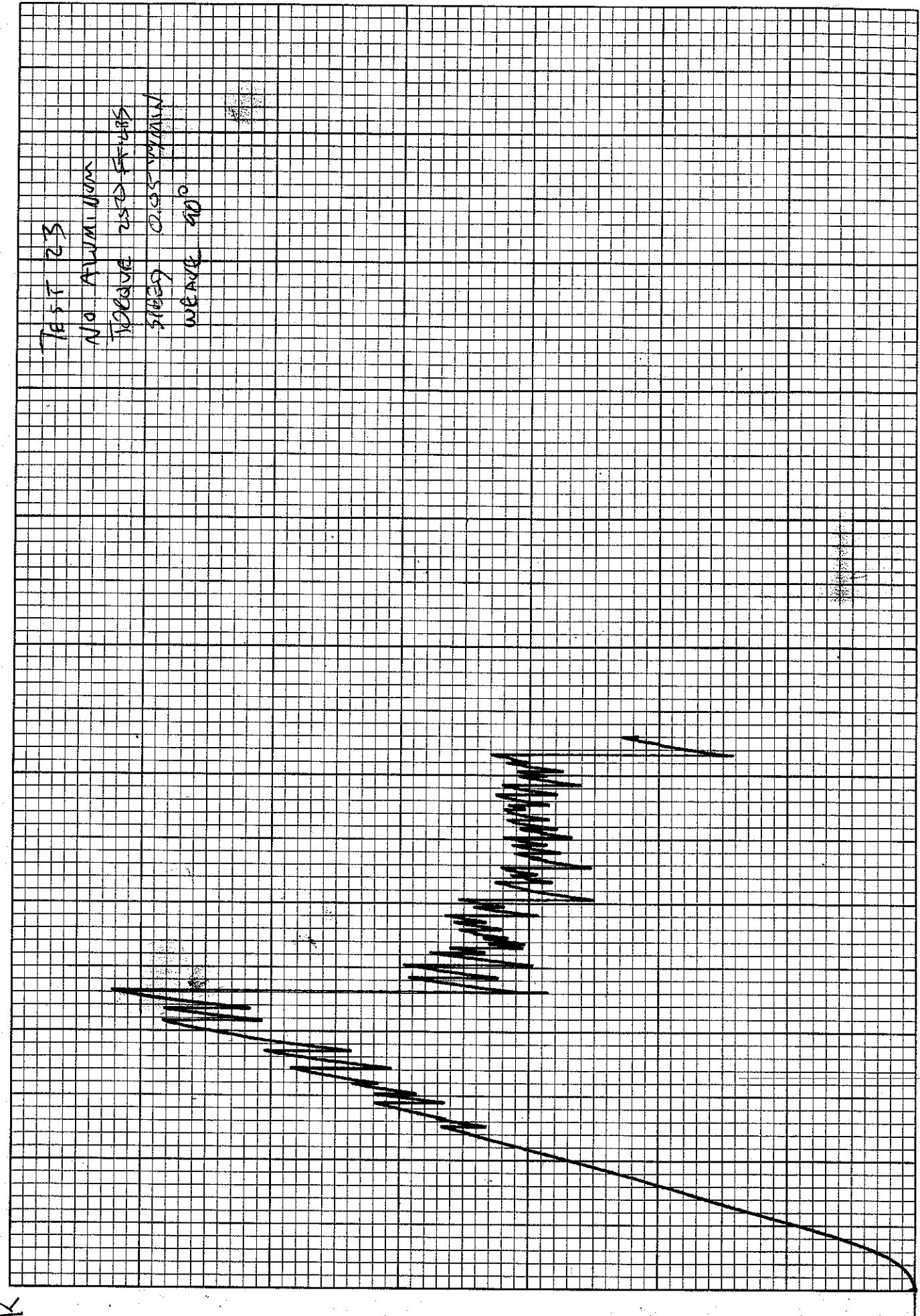
 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

(4K)

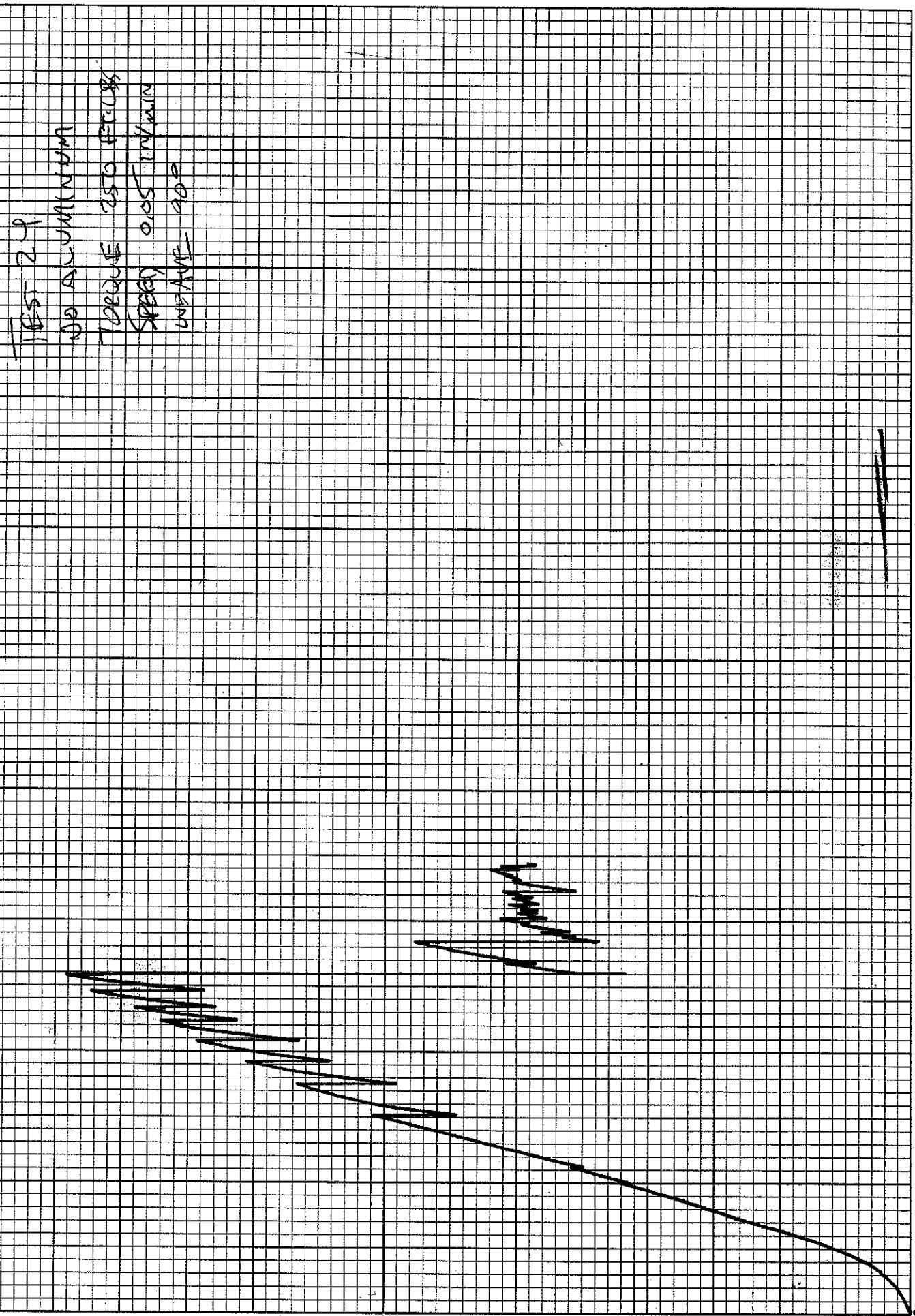


K&E 10 X 10 TO THE INCH • 7 X 10 INCHES
KELIFFEL & ESSER CO., MADE IN U.S.A.

46 0780



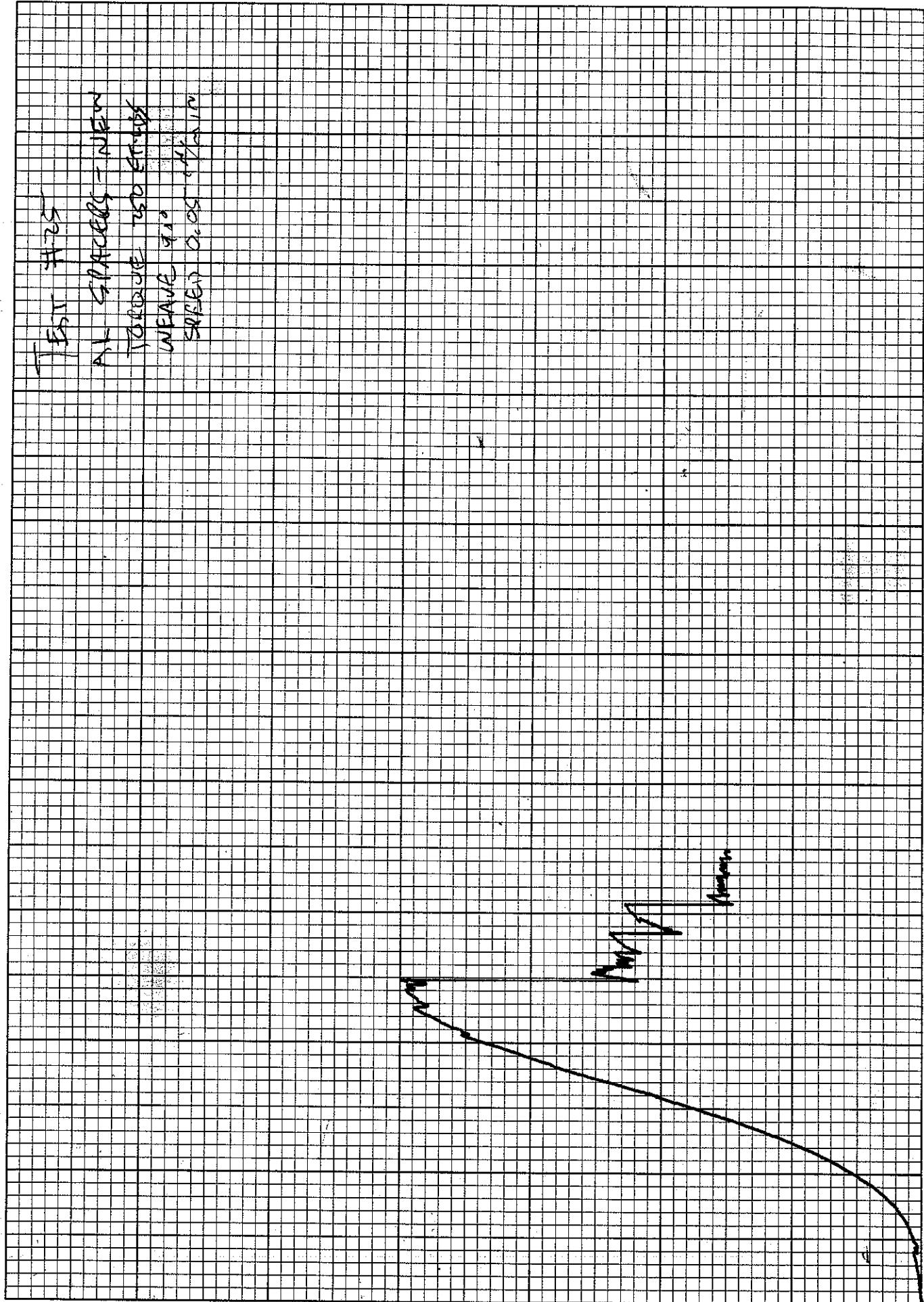
46 0780

 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO., MADE IN U.S.A.

K⁺ 10 X 10 TO THE INCH • 7 X 10 INCHES
KEIFFEL & LESSER CO. MADE IN U.S.A.

46 0780

MK



1815

34

26-1-12

AC SPACES

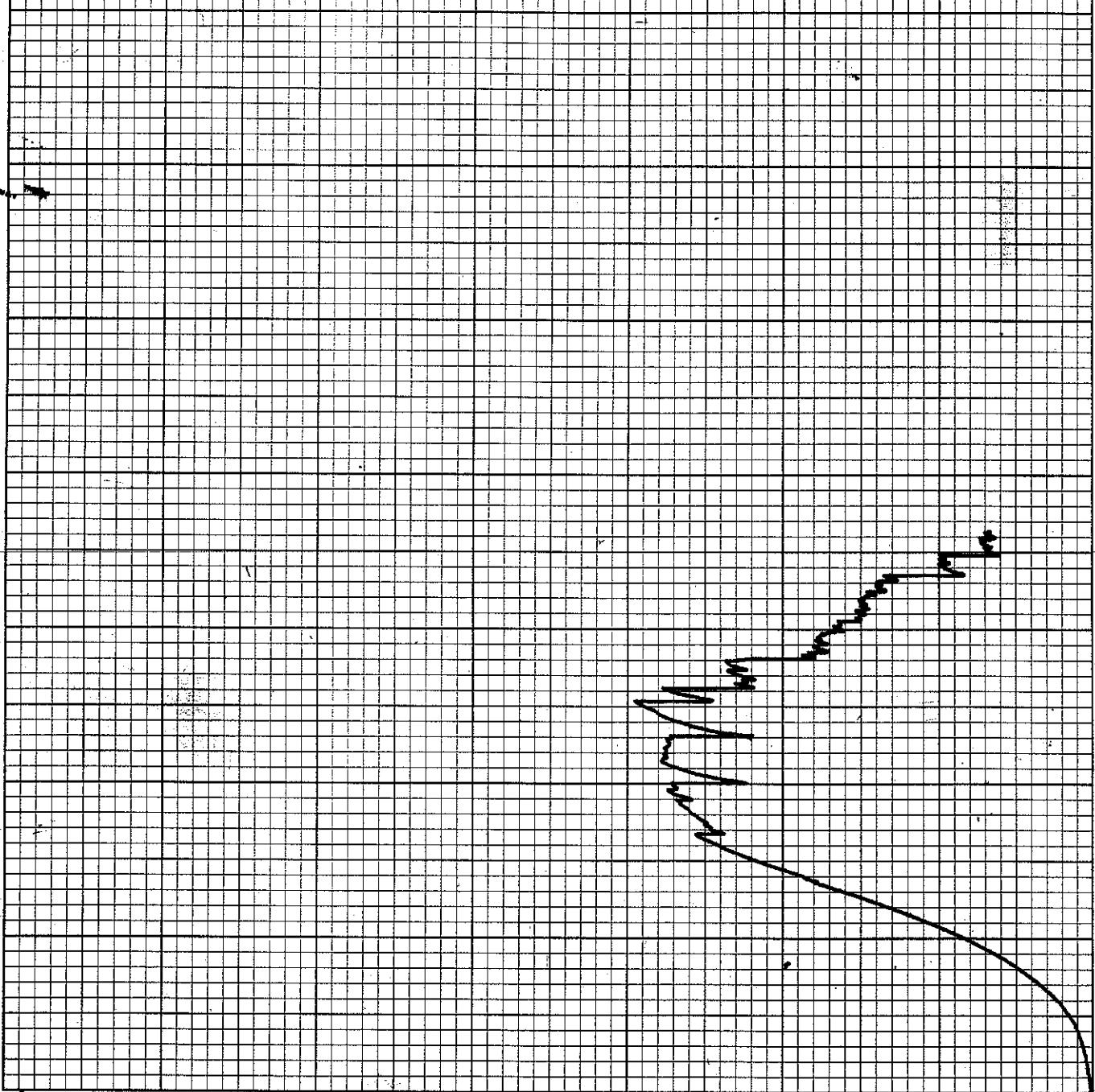
TGAEV - 200 (11/15)

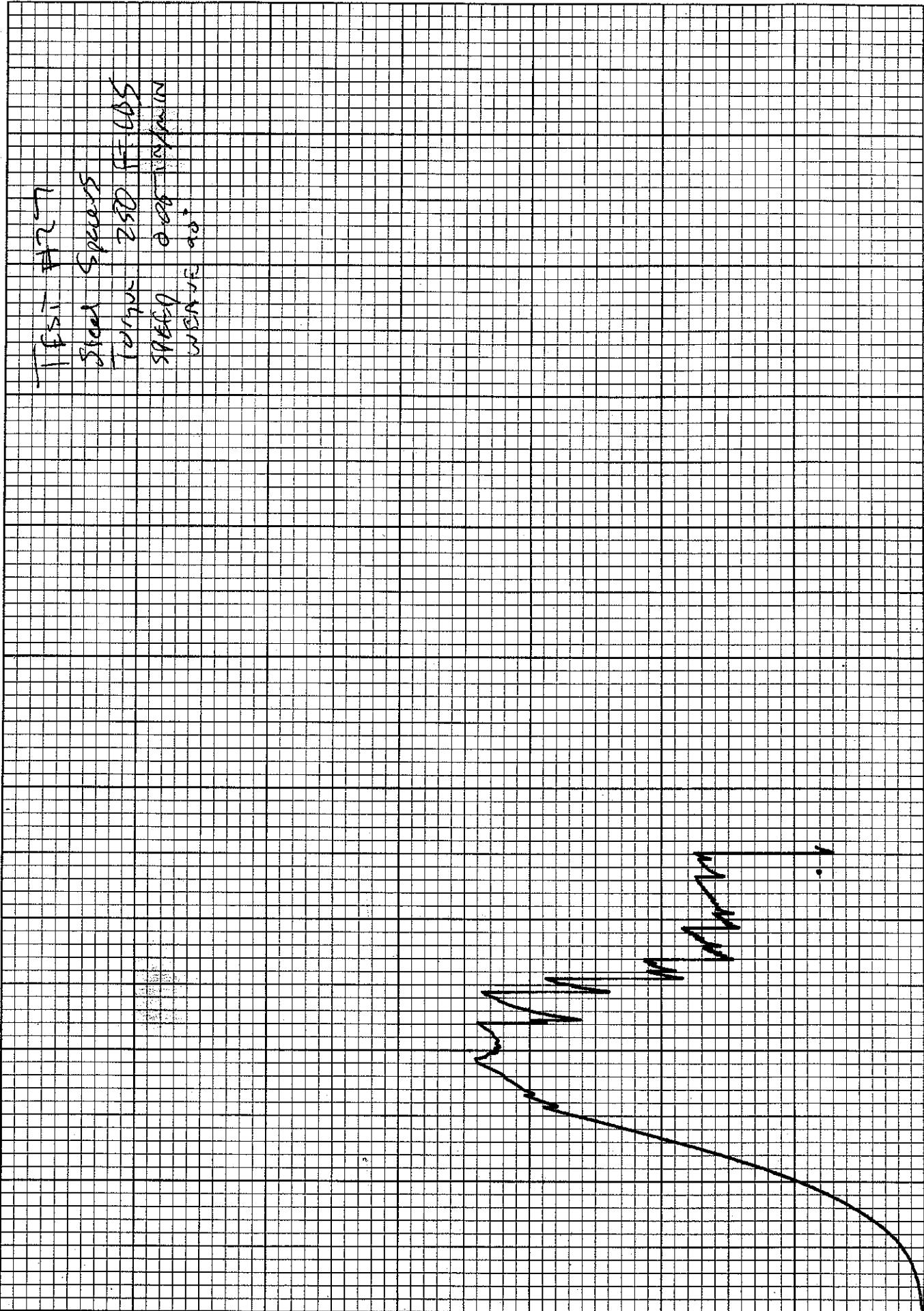
NINJA'S COOKBOOK

WISDOM OF GOD

11

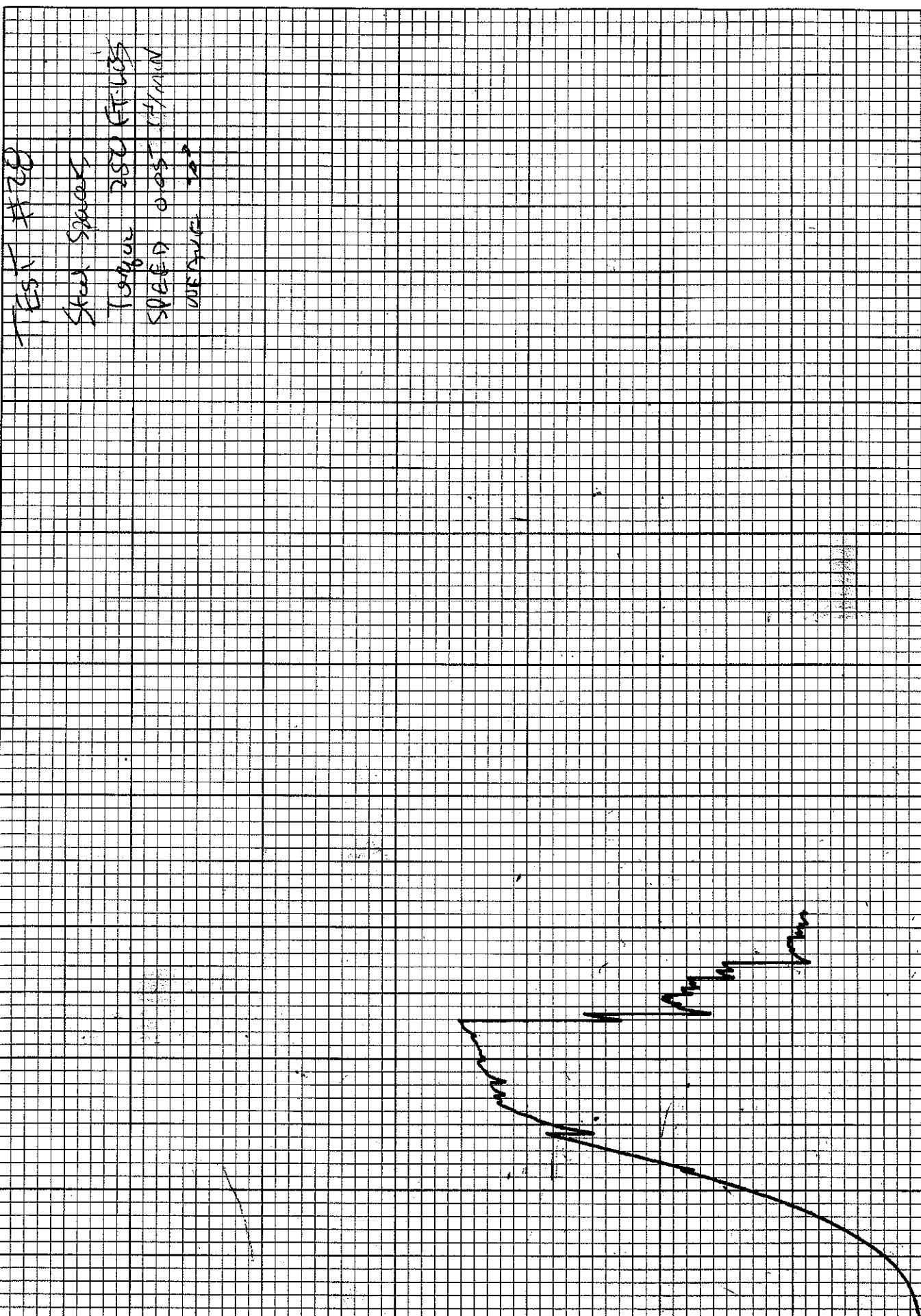
Bott afflicated





K 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0780



K* 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & SHERE CO. MADE IN U.S.A.

46 0780

